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SUBJ: Comments on the Confidence Removal Goal (CRG) Approach to Site Remediation as proposed by Gradient Corporation

(D1) "Applying Hazardous Waste Site Cleanup Levels: A Statistical Approach to Meeting Site Cleanup Goals on Average" - paper by Teresa S. Bowers, Neil S. Shifrin, and Brian L. Murphy of Gradient Corporation, submitted to Environmental Science & Technology, November 1994.

(D2) "A Model Relating Post Remedial Soil Concentrations to Exposure" by Brian L. Murphy and Teresa S. Bowers of Gradient Corporation, Proceedings of the Third Annual NE Environmental Exposition, May 1991.

(D3) Memo from David Merrill, Gradient Corporation to Jeff Dodd, EPA Region III, dated August 23, 1995 regarding "Input Parameters for the CRG Calculation".

(D4) Memo from David Merrill, Gradient Corporation to Jeff Dodd, EPA Region III, dated August 2, 1995 regarding "Statistical Issues at the METCOA Site"

I will begin with my understanding of the CRG approach, as explained in document D1:

Assumptions made in CRG Calculations :

(A1) The pre-remedial distribution of contaminant concentration (c) is log-normal, given by equation (1) on page 1 of Supplementary Material attached to document D1.

(A2) The post-remedial distribution is same as the pre-remedial distribution for $0 < c < c^*$, and equals the delta-function at $c = c^*$, as given by equation (3) on page 2 of Supplementary Material attached to document D1.

Steps of CRG Calculations:

Step 1 -

A mathematical expression for the ratio

$$\alpha = \frac{\mu'}{\mu} = \frac{\text{mean of post - remediation distribution}}{\text{mean of pre - remediation distribution}}$$

is derived from the assumptions A1 and A2.

Step 2 -

Equate the desired value of the ratio

$$\frac{\text{mean of post - remediation distribution}}{\text{mean of pre - remediation distribution}}$$

to the expression of Step 1 above. This yields equation (3) on page 5 of the document D1 [which is same as the equation (21) on page 7 of Supplementary Material attached to document D1] :

$$\alpha = \frac{1}{2}\left[1+2F\left(\frac{1}{\ln\gamma}\ln\frac{c^*}{\eta}-\ln\gamma\right) + \frac{c_0}{\eta}e^{-\frac{(\ln\gamma)^2}{2}}\left\{1-2F\left(\frac{1}{\ln\gamma}\ln\frac{c^*}{\eta}\right)\right\}\right]$$

F = standard normal cdf

Step 3 -

Solve the above equation for c* (CRG) in terms of the input values of the other parameters

α, γ, η, and c_0.

MY COMMENTS ON THE CRG APPROACH:

(1) The CRG approach is based on the assumptions A1 and A2. The first assumption (A1) apparently has been verified by Gradient Corporation. The second assumption, however, **has not been verified.** I recommend that, before using the CRG approach, it should be statistically verified that the second assumption (A2) is reasonable.

(2) The value of c* (CRG) obtained by solving the non-linear equation given in Step 2 above depends on the input values of c_0 (clean fill concentration) , and the two unknown population parameters γ and η. Since γ and η are estimated from sample data, the CRG c* is also an estimate, and suffers from sampling uncertainties. This is recognized by Bowers et. al. on page 9 of the document D1. For this reason, the CRG was defined as the value of c* that "**corresponds to the lowest value of the removal goal that results from**

any estimate of the mean between the upper and lower confidence limits" (see 1st paragraph, page 9, D1). *I suspect that Bowers et. al. intended to compute c* as the minimum value of the solution of the equation of Step 2 above, with the minimum taken over all values of* γ and η *consistent with the sample.* I recommend that, instead of substituting the UCLs for γ and η (as explained in document D3), 95% confidence interval be found for both γ and η, and the minimum c* value be found over this region of γ and η values. Since the equation of Step 2 is highly non-linear, this will result in a smaller value of c*. I would also like to add that sensitivity analysis should be performed with respect to c_0 value.

(3) If assumptions A1 and A2 turn out to be reasonable (as verified by pre-remediation and cleanup verification data), it is not at all clear how the statistical verification of cleanup be performed, since the normal or log-normal theory based formulas will not be applicable in this case.

ADDITIONAL REMARKS:

(1) As I had mentioned earlier, there are two valid statistical approaches that can be used for the METCOA Site data - Kriging, and the Population Partitioning Method of Singh et. al. (Mathematical Geology, Vol. 26, 1994, pp. 361-388). I have not had the time to complete the geostatistical analysis using the above two approaches.

(2) The METCOA Site data was apparently shown to be log-normal, and the UCL based on log-normal theory shows the need for remediation. If the CRG approach now shows that there is no need for ANY remediation, then something is wrong somewhere (a few possibilities are: the assumptions for using the CRG approach are not met, or the calculated CRG value is incorrect).